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Global Trends in Raw Materials Consumption

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After the 1973 oil shock, demand for raw materials — especially base metals — declined drastically. The most plausible explanation, supported by statistical evidence, appears to be that materials-saving technological changes have accelerated, probably because of higher energy prices.

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This paper — a product of the International Trade Division, International Economics Department — is part of a larger effort in the Bank to understand the changes in raw materials consumption in order to better assess the prospects for developing countries' exp-orts of those materials. Copies are available free from the World Bank, 1818 H Street NW, Washington DC 20433. Please contact Sarah Lipscomb, room S7-062, extension 33718 (25 pages). November 1991.

In this review of consumption of base metals, steel, and agricultural raw materials, the author focuses on the causes for the drastic slowdown in the consumption growth rate after the first oil price shock. From a range of 4 percent to 10 percent annually for most metals, the growth rates declined to 1 percent to 2 percent. Whether the post-1973 decline in demand for raw materials represents an irreversible structural change is important for developing countries that depend heavily on exports of those commodities. And views on this issue have been divergent.

The fact that the decline started when oil prices increased suggests that the energy-saving drive, through material substitution and technological changes, and the adverse macroeconomic impact of higher energy prices had detrimental effects on consumption of these materials. For agricultural raw materials, the decline has been much less pronounced. Any increase in consumption of cotton and natural rubber that resulted from higher costs of synthetic fibers and rubber must have been relatively small.

Most of the decline in raw materials consumption occurred in the industrial economies. In developing countries, the trend increase in the intensity of raw materials consumption per unit of output continued with only temporary interruptions at times of high oil prices. This was because of relatively rapid expansion of materials-intensive sectors and lags in adapting to the latest materials-efficient technologies. The developing countries — especially the rapidly industrializing countries — will continue to provide the main growth market for raw materials in the 1990s.

Statistical tests of alternative hypotheses suggest that the downturn has been only partly cyclical. There is not strong evidence to support the view that it was a one-time improvement in the efficiency of raw materials use.

The most plausible explanation, supported by statistical evidence, is that materials-saving technological changes have accelerated, probably because of higher energy prices. Whether those changes will continue at the accelerated rate when energy prices are lower remains to be seen. Recent data suggest that the rate may already have slowed down, which supports a more cautiously optimistic outlook for developing countries' exports of raw materials than prevailed in the early 1980s.

Global Trends in Raw Materials Consumption

by
Boum-Jong Choe

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I. INTRODUCTION

This paper reviews movements in raw materials consumption over the past 30 years. Included in this review are all base metals (aluminum, copper, lead, nickel, tin, and zinc) and steel, and important agricultural raw materials (cotton and rubber). These primary commodities share the common characteristic that they are used as inputs in manufacturing and construction. Some metals and minerals (e.g., manganese, titanium, phosphate rock, etc.), energy commodities, and timber products are not included in this review for various reasons. The period reviewed is from 1961 to 1988.

A prominent characteristic of the metals market during the past 15 years has been its very slow growth. In some years consumption of several raw materials has even declined. Explaining the causes of this slowdown, in the face of moderate economic growth, has become a topical issue. The slowdown has important implications for a number of developing countries that rely heavily on exports of these materials. The severity and persistence of post-1973 declines in metals intensity per unit of GNP, as shown by Tilton (1985), prompted the conjecture that it may have been *structural*. This paper reviews the debate on this issue, including results of statistical tests.

Technological and scientific innovations have long been providing synthetic alternatives to primary or raw materials. In particular, the 1980s have witnessed significant advances in materials science, with a potential to save or replace primary materials in many end uses. These developments as they affect individual commodities are also reviewed.

The next section summarizes the trends in raw materials consumption. Section III reviews the technological developments relating to raw materials consumption. Section IV discusses the structural change hypothesis. The last section draws some conclusions.

II. TRENDS IN RAW MATERIALS CONSUMPTION, 1961-1988

Table 1 shows growth rates of raw materials consumption for major country groups. For all raw materials and all country groups except for nickel and rubber in developing countries, demand growth rates slowed drastically after the first oil price shock in 1973/74. The sharp decline in consumption growth has been a subject of great concern, especially to developing country producers of these commodities. Investigations as to its causes have generated considerable literature, which is reviewed in Section IV. Much of the literature, however, did not have the benefit of observing that growth rates of raw materials consumption sharply increased in industrial countries when oil prices collapsed after late 1985. Developing countries showed moderate increases in consumption but there has been no sign of an upturn from trend growth, except for tin and rubber. Growth rates of raw materials consumption in the formerly centrally planned economies of Eastern Europe and USSR were lower during 1986-88 than in any of the preceding periods.

It would seem more than a coincidence that such clear discontinuities in raw materials consumption growth took place at times of major changes in petroleum prices. Energy prices could affect raw materials demand in three ways: first, by changing the costs of synthetic substitutes; second, through energy-capital and energy-materials complementarity as inputs into production, both within any given production technology as well as through technical change induced by higher energy prices; and third, through its macroeconomic effects. Immediately following the first oil price shock, analysts expressed optimism for the future of raw materials, particularly rubber and cotton. They expected synthetic rubber, fibers, and plastics would become more expensive and therefore the demand for natural raw materials would increase. Subsequent experience showed that this expectation was too optimistic. Although cotton and natural rubber have made a comeback over the past 15 years (see Table 1), it was due more to changes in technology and taste than to relative costs (see next section). Market penetration of plastics accelerated, if anything, thanks to the energy-saving

TABLE 1: GROWTH RATES OF RAW MATERIALS CONSUMPTION

(Percent per annum)

	Industrial Countries			Developing Countries			Eastern Europe & USSR			World Total		
	A	B	C	A	B	C	A	B	C	A	B	C
Steel	5.5	-1.1	8.5	7.6	4.6	0.8	5.4	1.5	1.0	5.7	0.7	4.1
Aluminum	10.0	0.9	5.9	16.4	6.4	4.4	7.3	1.3	1.1	9.9	1.7	4.8
Copper	4.3	0.3	2.7	7.2	6.0	5.1	4.9	1.4	-0.5	4.6	1.3	2.5
Lead	3.4	0.0	2.4	7.0	3.8	1.0	5.6	1.2	0.5	4.2	0.9	1.7
Zinc	5.7	-1.2	3.2	6.9	5.6	4.0	6.1	1.5	3.1	5.9	0.6	3.4
Tin	1.8	-2.1	3.2	2.6	2.7	4.4	0.9	1.7	-2.0	1.8	-0.6	2.4
Nickel	6.9	1.2	9.7	6.4	7.2	2.6	3.7	2.3	-1.2	6.2	1.9	6.3
Cotton	-1.3	-0.1	0.2	5.4	3.5	2.2	2.6	0.3	-1.5	2.5	2.1	1.3
Rubber	3.8	1.5	5.2	5.9	5.8	13.2	0.1	-3.9	-10.8	3.5	2.3	6.9

Note: Growth rates are between two end-years of the following periods:

A: 1961-73
B: 1973-88
C: 1986-88

Source: International Economics Department, World Bank.

drive in industrial countries. It seems clear, therefore, that the technological and macroeconomic effects of the oil shocks dominated over the substitution effect away from synthetics; overall, higher energy prices had a depressing effect on raw materials demand.

Divergent trends in growth rates between industrial and developing countries partly reflect the relocation of raw materials-using industries from industrial to developing countries. Consumption statistics for raw materials, as those in Table 1, are usually compiled at the initial stage of processing; for example, consumption of raw cotton by cotton mills. Consumption in the form of intermediate and final products, such as cotton fabrics and clothing, is not captured in the statistics. A large part of the high growth rate of cotton consumption in developing countries reflects the persistent movement of textile manufacturing from high-income to low-income countries. The same process also has been taking place in one degree or another for all other raw materials-using industries.

Since Malenbaum (1973), analyses of metals consumption have focused on explaining changes in the intensity-of-use, or metals consumption per unit of output. Charts 1-3 show the changes in metals intensity in the industrial and developing country groups with respect to GDP and the investment component of GDP, or GDI.[1] These confirm Tilton's (1986) observation of a sharp post-1973 downturn in the intensity of steel and non-ferrous metals per unit of GDP. For agricultural raw materials, however, the 1973/74 benchmark does not provide a clear break in the long-term trend.

The charts further show that, for the metals, declines in the intensities with respect to GDI have been less pronounced than for GDP. This is because consumption of metals is more closely linked to production of capital goods than to total output. Before the first oil price shock, metals consumption per unit

[1] Base metals and cotton and rubber are aggregated into totals for non-ferrous metals and agricultural raw materials, using 1979-81 prices as weights.

of GDP and GDI were roughly constant in industrial countries, while in the developing countries, the intensities had been increasing. The intensities in the industrial countries declined sharply in the wake of the two oil price shocks and ensuing economic recession. In recent years, the intensities have stabilized (or picked up slightly) at relatively low levels. In the developing countries, the upturn in the intensities continued by and large throughout the period, although with some interruptions following the oil price shocks.

The data allow us to calculate the contribution of changes in the share of GDI in GDP to changes in the metals intensity of GDP. Between 1961 and 1973 in the industrial countries, the base metals intensity of GDP increased at 1.3% p.a., and about half of this increase resulted from the increase in the investment share of GDP and the other half from the increase in the intensity per unit of GDI. Between 1973 and 1988, however, the metals intensity of GDP declined at 2.3% p.a.; 57% of the decline was contributed by a decrease in the share of GDI in GDP and the remainder by reduced metals intensity of GDI. This finding contrasts with Tilton's conjecture that the post-1973 decline in the metals intensity of GDP was more due to metal-saving technological change and substitution away from metals than to changes in the output mix.[2] His statement was based on data up to 1982. Since 1982, the overwhelming direct cause of decline in metals intensity of GDP has been the downturn in the investment share of GDP. In the developing countries, the metals intensity of GDP increased during both 1961-73 and 1973-88, and the dominant cause of the increase has been the steady rise in the metals intensity of investment, more so during 1973-88 than during 1961-73.

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[2] Examples of such technological changes and substitutions are numerous. Thinner coatings of tin, nickel and zinc as well as the use of thinner- and smaller-gauge aluminum and copper lead to savings of these metals. The oil price shock of 1973 stimulated the automobile industry to downsize and substitute for better fuel efficiency, by means such as smaller batteries, and substitution of copper for aluminum and plastics. The fiber optics technology almost totally eliminated copper use in telecommunications.

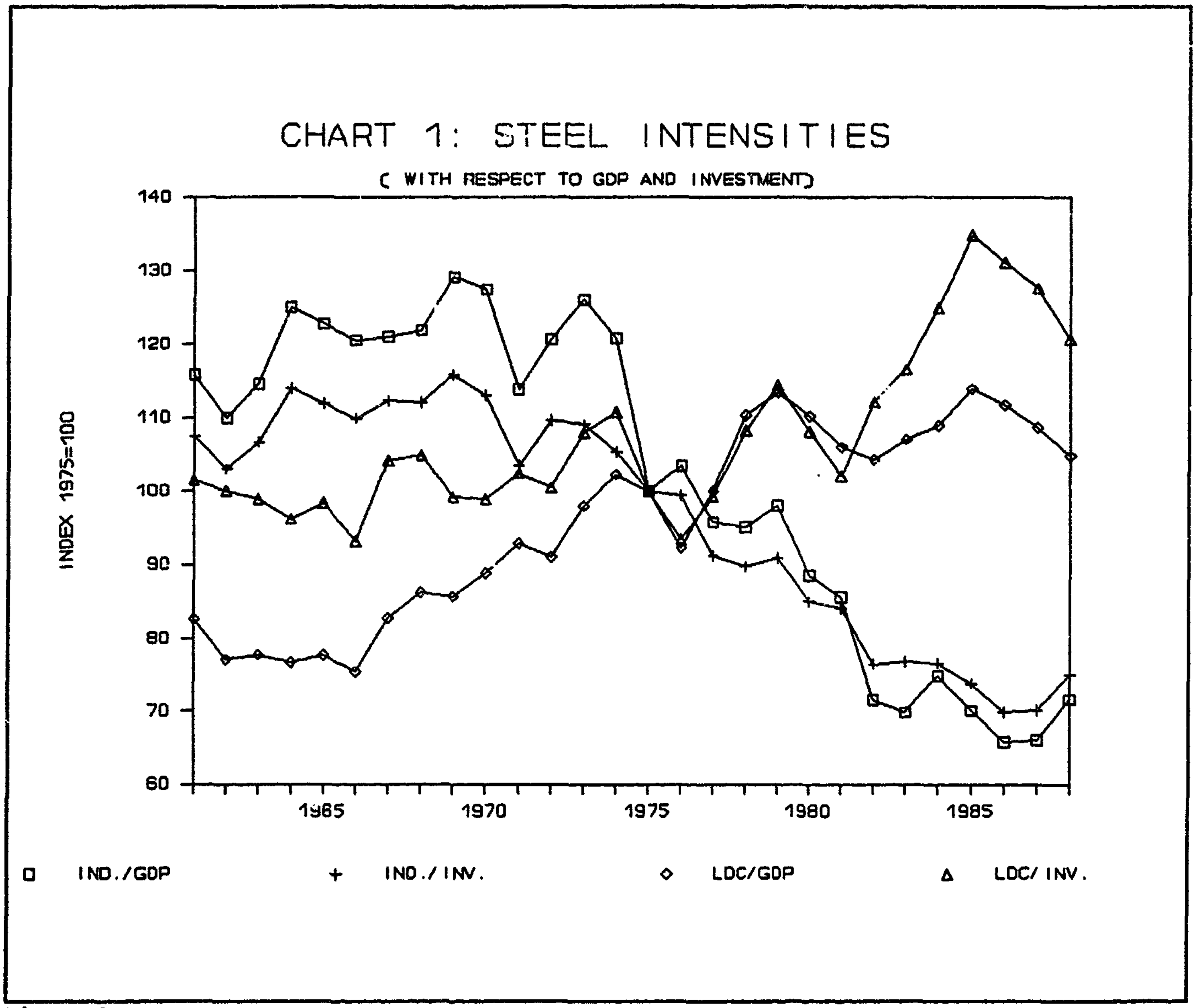
CHART 1: STEEL INTENSITIES
(WITH RESPECT TO GDP AND INVESTMENT)
INDEX 1975=100
140
130
120
110
100
90
80
70
60
1965
1970
1975
1980
1985
IND./GDP
IND./INV.
LDC/GDP
LDC/INV.

Figure 1

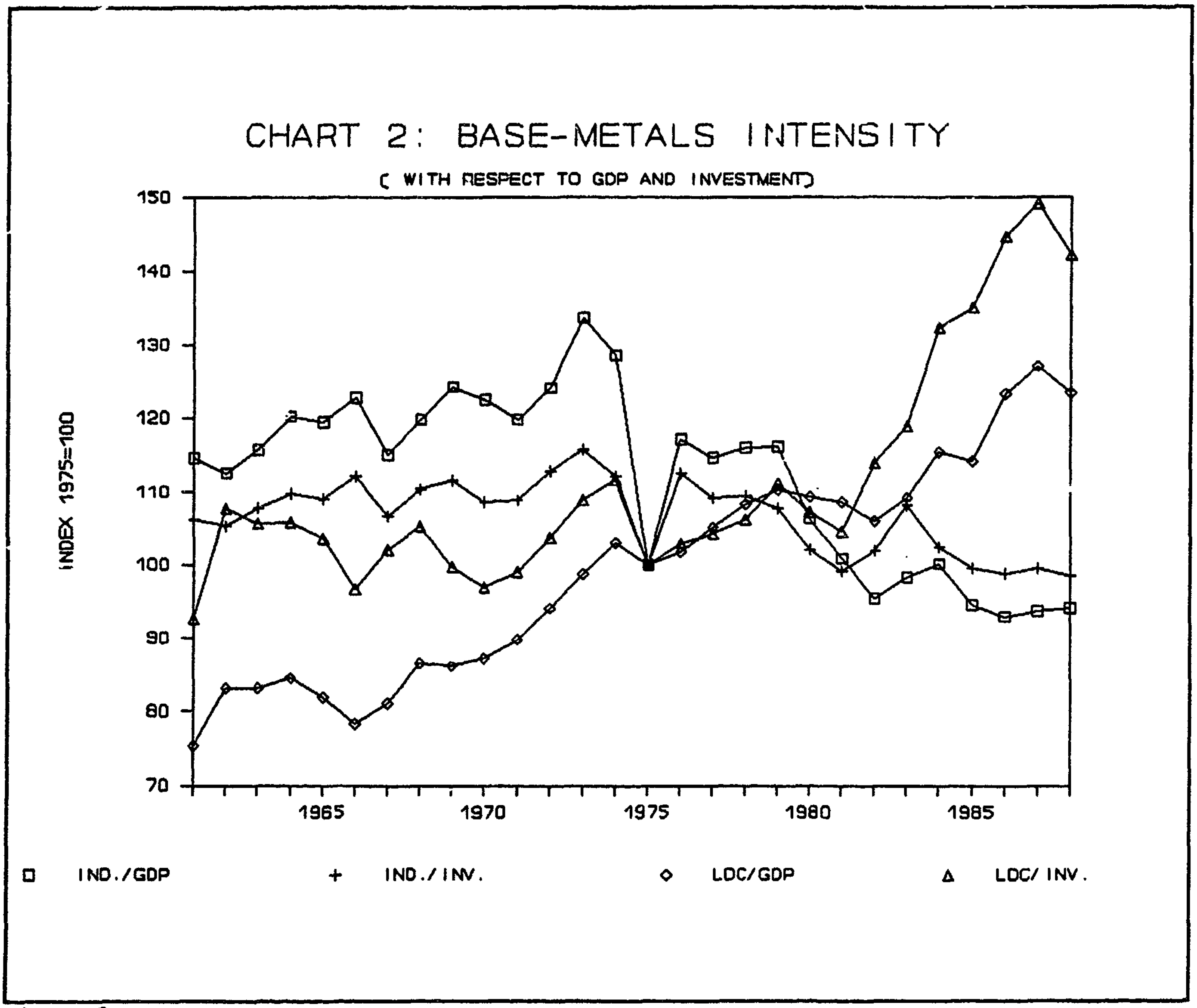
CHART 2: BASE-METALS INTENSITY
(WITH RESPECT TO GDP AND INVESTMENT)
INDEX 1975=100
150
140
130
120
110
100
90
80
70
1965
1970
1975
1980
1985
IND./GDP
IND./INV.
LDC/GDP
LDC/ INV.

Figure 2

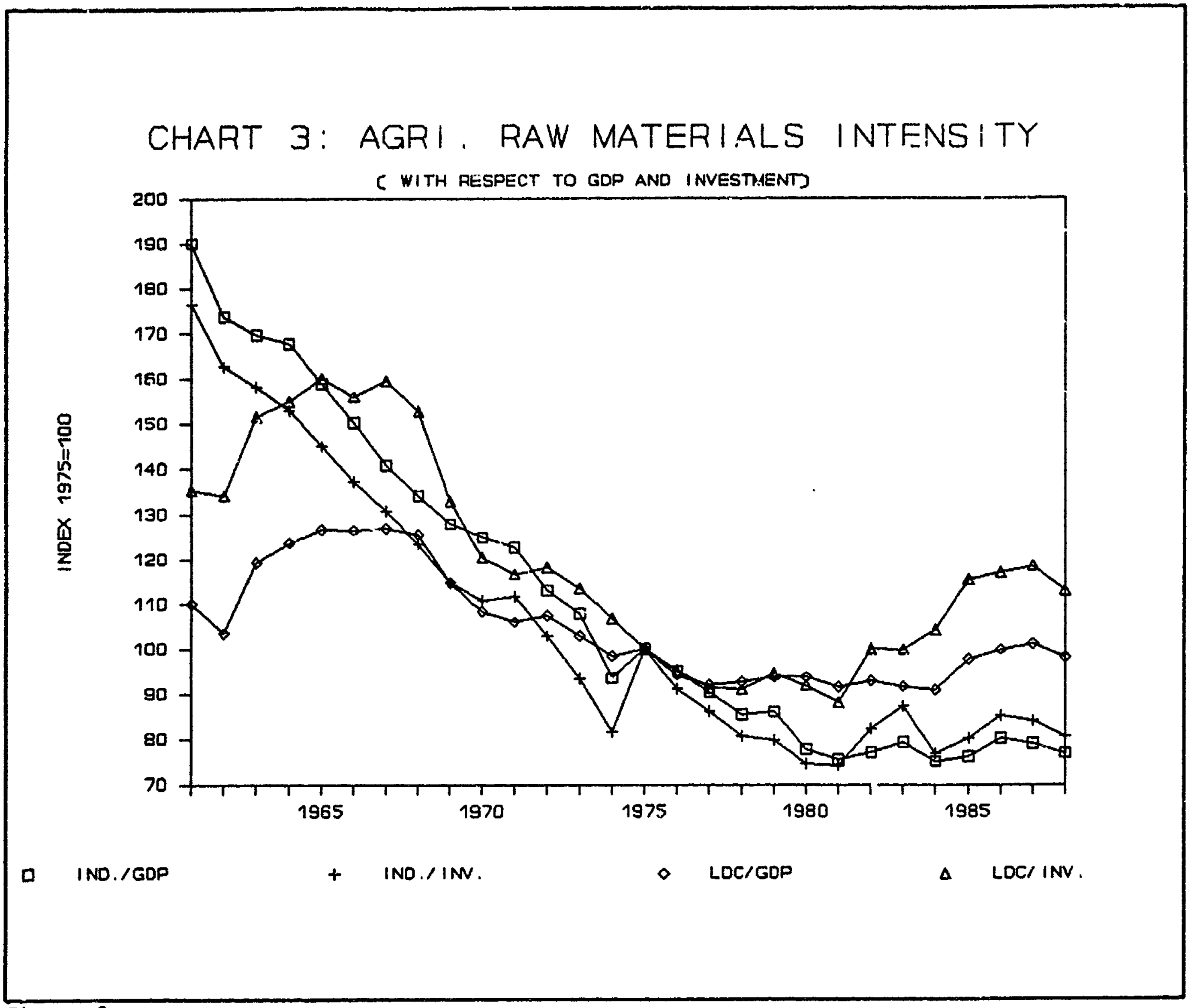
CHART 3: AGRI. RAW MATERIALS INTENSITY
(WITH RESPECT TO GDP AND INVESTMENT)
INDEX 1975=100
200
190
180
170
160
150
140
130
120
110
100
90
80
70
1965
1970
1975
1980
1985
IND./GDP
IND./INV.
LDC/GDP
LDC/INV.

Figure 3

III. TECHNOLOGICAL DEVELOPMENTS IN RAW MATERIALS CONSUMPTION

Savings in raw materials consumption have been achieved for the entire spectrum of their life-cycle, from mining and processing to end use and recycling. At the mining and processing stages, there have been technological improvements to enhance metals recovery from ores. In the case of copper, the solvent extraction/electrowinning process (SxEw) allowed large copper recovery from waste dumps. The continuous casting technology in steel-making saved not only energy but also reduced iron ore losses from 10% to 2-4%. However, most savings have been attained in various end-uses of materials through: (i) product downsizing and miniaturization, (ii) improvements in the efficiency of use, and (iii) development of substitutes. Recently, savings through recycling of raw materials have come into focus, mainly out of concern for the environmental impact of materials wastage. In this section we will focus on technological developments in end uses and recycling for each raw material.

Steel

The most significant development in steel use has been the introduction of high strength low alloy steel (HSLA), which is about three times stronger than that of 10 years ago. Today, about half of the world's steel output is of the HSLA variety. Obviously, HSLA saves steel by delivering higher strength for less weight. This has been an important feature in the post-1974 period, when energy saving required less weight in automobiles, the most important market for steel.

The HSLA technology has been instrumental in protecting steel's market share in automobile manufacturing and other end uses. Steel's main competitors in automobiles have been plastics and aluminum. Plastics' main attraction in automobiles is its low weight, no rusting, and easy formability and hence low manufacturing cost. Its disadvantages are the lack of ductility and difficulty in recycling. Aluminum's advantage is its low weight.

Plastics have made significant inroads in automobiles, in interiors, bumpers, and various casings and containers. The weight of plastic materials used in the average automobile manufactured in Western Europe increased from 35kg in 1970 to 98kg currently, or from 3% of the total weight of the average car to 10%. US automobile manufacturers have been using more plastic per car than their European counterparts, but the gap has narrowed to about 10% above the European level in terms of the total weight of plastics used per car. The main area of future expansion of plastics use in automobiles is in exterior body panels. However, plastics are facing major obstacles in this application. First, plastics are more expensive than steel at a production volume of 50,000 units or more. Second, the lack of ductility of plastics puts it at a disadvantage in collision damage repair. Third, plastics do not yield a metallic surface finish, a highly desired quality by consumers. Fourth, difficulty of recycling has become an increasingly formidable problem for full-scale use of plastics in automobiles. There have been a few plastic-body models developed in recent years, but they have not become popular. Plastics are not likely to make major inroads in automobile bodies before the end of this decade. There are, however, a number of other applications of plastics in automobiles so that its use will continue to increase although at a slower rate than in the past.

The potential for substitution of steel by plastics also exists in the construction sector. Polymer-reinforced concrete is lighter and more durable than steel-reinforced concrete, and has been used in construction of tunnels and canals.

The automobile industry also has been looking into advanced ceramic materials for use in engines and other heat-resistant components. The ceramic engine technology still has a long way to go in order to find widespread applications. Various ceramic, polymeric, and metallic composite materials are continuing to be developed to improve performance characteristics of specific components that have been made with conventional materials, including steel. However, costs of such materials tend to be high, and thus the total displacement of steel by such materials probably will not amount to a substantial proportion [see Ilschner (1986)].

Copper

Product miniaturization and substitution have reduced the demand for copper. The effects of miniaturization, however, have been largely offset by increased demand for products, stimulated in part by lower product prices. Recently, there have been indications that substitution for copper has slowed down. For example, copper consumption per unit of automobile production has increased as more electronic gadgets have been added.

Copper has been under pressure from various competing materials, notably, aluminum, plastics, and optical fibers. This competitive pressure covered practically all end-uses of copper, such as electrical wiring, plumbing tubes, heat exchange equipment, and various alloys. Aluminum almost totally displaced copper in high-tension electrical transmission cables. However, building wires are still predominantly made with copper. Furthermore, copper wires are the standard in practically all electrical equipment, ranging from power generators to computers. Thus, copper is still used extensively in many industrial activities. Aluminum also has been displacing copper in heat exchange equipment, such as automobile radiators (because of its lighter weight) and cooking utensils. This process is likely to continue, particularly in the United States and Japan where copper still holds the dominant share of the market.

Plastics hold a clear cost advantage over copper in plumbing tubes and fixtures. There is, however, the perception that plastic pipes are somehow inferior to copper pipes, and perhaps unreliable. However, copper is highly vulnerable in this market; the quality of plastics could improve to eventually dominate the market.

The most recent trend in substitution against copper is the use of optical fibers in telecommunications. Because of its superior technical advantages, optical fibers have completely dominated the long-distance communications cable market. However, Tan (1986) estimates that the total amount of copper consumption to be lost to optical fibers will be only about 3% of total annual copper consumption. At the user-end of telecommunications, copper wires are used inside and outside various terminals. Since optical fibers would lower costs of telecommunications and hence increase its use, the net impact on copper consumption may not be all negative. A major technological innovation looming over the horizon is the possibility of room-temperature superconducting material, which potentially could have a devastating effect on copper demand.

Aluminum

Until very recently, aluminum has enjoyed the most spectacular demand growth among base metals. This was made possible by aggressive product development and market penetration. It is widely believed that the strategy, although still being vigorously pursued, is increasingly facing the problem of market saturation and competition from high-tech composite materials.

The most significant technological development in the use of aluminum for packaging has been the progressive "thinning" of aluminum beverage cans. Since aluminum is more expensive than tinplate (tin-coated steel), it was by means of thinning that aluminum was able to penetrate the beverage can market. In food packaging that requires vacuum packing, thinning was not feasible; as a result the market largely remains in the domain of tin cans and plastics.

The light weight and relatively high strength of aluminum has been the main attraction in applications where weight reduction is a major concern, as in aircraft and automobiles. Aluminum and aluminum/titanium alloys have been the main materials of aircraft; a Boeing 767 aircraft is made of 81% aluminum, 14% steel, 3% composite material, and 2% titanium. It was thought that composite materials would overtake aluminum in the 1990s as the main material of commercial aircraft. However, it seems unlikely that this will happen because of the massive investments required for the transition and the relatively high cost of composite materials. The aluminum industry continues to come up with improved aluminum alloys with greater strength and fatigue resistance, to find applications not only in aircraft and automobiles, but also in ships and trains (for high-pressure containers), and numerous other applications.

Lead

Batteries have been the most important end-use sector for lead. About 81% of the net increase in lead consumption during 1986-88 was for increased battery production. End uses such as cable sheathing, alloys, and gasoline additives have been declining in absolute terms as well as in terms of their relative shares.

Since the first oil price shock of 1973/74, automotive batteries have undergone major technological changes that led to downsizing of batteries without sacrificing power. This was achieved mainly by the development of thinner grids that reduced the lead content of typical automotive batteries. It is estimated that the lead content of an average battery in the United States declined from 10.5 kg in the early 1970s to about 7 kg in recent years and has stabilized at that level. Similar declines, from 9.7 kg to 6.5 kg, are also estimated for Japan. These declines, however, have been more than compensated for by increases in battery production. During 1983-88, world battery production increased at 3.5% p.a.

The average battery life also has increased -- up to 5 years in Europe where ten years ago it was 2.5 to 3 years. In the United States and Japan, an average battery life of 3.3 to 4 years has become the norm. Recently, the increasing use of electronic equipment in automobiles has demanded greater reserve power in batteries. Research to improve battery performance is now focused on providing reserve power as well as cold-cranking ability. Until such improvements have been made, these demands may result in a temporary increase in lead consumption per batteries.

Data available for the United States indicate that batteries used for industrial purposes have been the most rapidly increasing segment of lead consumption, increasing at 9.6% p.a. during the last five years (in terms of the total sales value of industrial batteries). The fastest growing industrial uses for batteries are in providing stand-by power, which means large batteries to store electricity to provide emergency power. A particularly promising application of large-scale batteries is in peak load management, currently under experimentation at US electric utilities.

Demand growth in rolled and extruded lead products, and in pigments and other compounds, is likely to be mostly offset by declines in markets for cable sheathing, alloys, and gasoline additives. Plastics will continue to replace lead in cable sheathing, although at slower rates than in the past. Many developing countries still use leaded gasoline and this practice will come under increasing pressure because of health and environmental concerns. For the same reason, the lead content of solder, the main lead alloy, will continue to decline. Lead in pigments and other compounds that do not pose health risks has been increasing and will continue to increase. Among the rolled and extruded products and other miscellaneous uses, the promising areas for future growth are in nuclear waste management and protection from radiation, lead roofing and pipes, and in galvanizing.

Zinc

The largest and the fastest growing market for zinc is the galvanizing market, currently accounting for about half of zinc consumption. The galvanizing market for zinc has been adversely affected by two technological developments. One is the progressively thinner coatings of zinc and the other is the introduction of zinc alloys such as Galvalume (55% aluminum, 43.5% zinc, and 1.5% silicone) and Galfan (5% aluminum and 95% zinc) as the coating material. Increased adoption of electrolytic galvanizing in place of the hot dipping method, because of the former's more uniform and thinner coating properties, has reduced the overall thickness of zinc coating in galvanized steel. In electro-galvanizing itself, the coating thickness has been reduced through improvements in technology. Galvalume provides better corrosion protection than does zinc at the cost of some undesirable properties. Galfan has shown greater corrosion resistance than zinc without losing the desirable properties of zinc. It is estimated that between the 1960s and the early 1980s, zinc consumption per ton of galvanized steel declined by 8.7%. Continued research and development in this area is expected to bring about further declines in the zinc intensity of galvanized steel. However, the drive to improve the product quality of manufactures will require better corrosion protection and hence more widespread use of galvanized steel. The most dramatic example has been in the automobile sector, where, during the 1982-86 period, the amount of zinc used for corrosion protection in an average automobile increased by 45% in the United States. Many other product categories offer opportunities for increased use of galvanized steel, such as construction beams and posts.

Zinc-based alloys for diecasting have widespread industrial applications, the most important of which is in automobiles. However, zinc diecasts in automobiles have been under intense competitive pressure from plastics and aluminum as the drive for fuel efficiency has required lighter products. The zinc industry's answer to this challenge was the introduction of thin-walled diecasts which helped stabilize the share of zinc diecasts but reduced the amount of zinc used. As a result, zinc diecasts used per automobile produced in the United States declined from 64 lb in 1967 to 20 lb in 1986. Consumption of zinc-based alloys is expected to grow roughly in line with industrial production, unless the pressure of substitution intensifies because of the high cost of zinc or for other reasons.

Brass and bronze, long used widely for a variety of purposes, are considered to be mature products with little scope for market expansion. Their consumption has generally been declining. (Brass is used mainly in plumbing fixtures and for heat-exchange components such as automobile radiators.) Both of these markets have been and will continue to be under strong competitive pressure from plastics and aluminum.

Nickel

Nickel is used mostly in alloys with other metals. Such alloys have desirable properties, the most important of which are high resistance to corrosion and high tensile strength at elevated temperatures. Nickel is also used for electro-plating and high-technology electrical batteries; its largest potential use is in battery-operated electric cars. Stainless steel has been the largest and fastest growing market for nickel. Various other nickel-based alloys also have shown good growth.

Nickel could be substituted by other metals as the alloying element or by other non-nickel-based alloys. However, in most cases substitution of nickel entails a sacrifice of nickel's unique physical and chemical properties, or require higher cost. The most serious competitor is aluminum, which can substitute for stainless steel and nickel/chromium alloy in automobile applications.

Cotton and Rubber

Synthetic fibers and rubber provided the classic examples of natural raw materials being displaced by synthetic substitutes. The share of synthetic fibers in world total fiber consumption increased from 37.5% in 1970 to 46% in 1977, and has remained in the 45-49% range since then. There have not been pronounced and sustained increases in this share after the oil price shocks.

The share of natural rubber in total rubber consumption declined steadily from 53% in 1960 to 34.6% in 1970 and to 30% in 1988. During the last 15 years, the increasing market share of radial tires in total tire consumption has helped to maintain the market share of natural rubber. Natural rubber has found use in a wide range of producer and consumer goods other than tires. Today, tires account for about half of natural rubber consumption. Technology has played a major role in developing non-tire markets for natural rubber, such as hoses, belts, shoes, gloves and medical applications.

IV. STRUCTURAL CHANGE IN RAW MATERIALS DEMAND

The severity and persistence of post-1973 declines in metals intensities (see Section II) prompted the conjecture that it may have been "structural." Although this term has not been defined precisely, it broadly implied permanent and irreversible shifts in demand for raw materials, and hence a pessimistic outlook for developing countries heavily dependent on exports of those materials. This section summarizes the current state of the debate on this subject.

The post-1973 trends in metals consumption permit three broadly different interpretations.[3] The first is the cyclical interpretation, which views the decline in metals intensity as resulting largely from a prolonged downturn in economic growth and investment. This view rejects the notion that there has been a sudden acceleration in the rate of materials-saving technological progress. Technological change continuing at the long-term trend rate does not qualify as a structural change. The recent upsurge in metals consumption has given new life to this view, as expressed by Crowson (1989), for example. The second is the view that after the first oil price shock there has been a one-time flurry of

[3] Since the trends in cotton and rubber consumption do not lend themselves to a structural change interpretation, the following discussion will focus only on metals.

materials-saving technological innovations and such changes are here to stay. Metals intensity has been permanently shifted downward and will resume the long-term trend but from the lower level, even if oil prices return to the pre-1973 level. The third view is that high oil prices have set in motion a process that permanently changed the materials demand relationship, accelerating the rate of substitution, technological change, and changes in the mix of output. Drucker (1986), for example, writes that the raw materials economy has become "uncoupled" from the industrial economy. Larson, Ross and Williams (1986) cite the following as causes of "fundamental structural change": substitution of new materials; design changes to enhance efficiency of materials use; saturated consumer markets; and increased use of less materials-intensive goods. The proposition outlined by these authors was generally termed the "structural change hypothesis."

These different interpretations of what has happened over the last 15 years have important implications for the future of raw materials. However, it is not easy to assess their relative merits with the available information. One way of testing their validity is by standard econometric hypothesis testing in the context of a demand model for metals. A formal test of the structural change hypothesis was carried out using an extended demand model for metals [see, Choe(1989)]. In an extension of the traditional metals demand models that have focused only on the prices of the metal and its close substitutes, the demand function is derived from an aggregate cost function that includes all relevant factor inputs. The motivations for this are twofold: tests for structural change require a fully specified demand model and the implications of energy price shocks during the period should be taken into consideration.

Suppose that output, Q, is produced with four variable inputs -- labor (L), energy (E), metal (M), and other materials (S) -- and one quasi-fixed input, capital (K). This is the familiar KLEM framework widely used in studies of aggregate factor demand. Further suppose that the cost function is quadratic, and assume biased technical progress (in Hick's sense) and non-constant returns to scale. Then, the metals demand function is expressed as:

$$M = \alpha_M + \alpha_t\, t + \beta_M\, p_M + \beta_E\, p_E + \beta_S\, p_S + \beta_Q\, Q + \beta_K\, K,$$

where p_M, for example, is the price of the metal and t stands for time trend.

In the context of the demand model above, structural change is defined as changes in the parameters of the model. The cyclical view asserts no change in the parameters has taken place. The one-time technical shift view may best be represented by a shift in the intercept term, α_M. The third structural change view would involve shifts in all or a subset of the parameters, particularly, α_t, β_S, and β_Q.

The model is estimated with US data. Note that the structural change hypothesis was advanced on the basis of US experience. A battery of Chow tests are performed for equality of coefficients for periods prior to and after 1973. To assess the significance of the additional variables introduced in the extended model, the same tests are also performed with the conventional demand model that does not include the energy price and capital variables.

The joint null hypothesis of no structural change in all parameters is tested first (see Annex Table 1 for test results). With the extended demand model, this hypothesis is rejected at the 5% significance level for all base metals except for zinc; with the conventional demand model, it is rejected for all base metals at the 1% significance level. Thus, the inclusion of energy and capital variables helps explain the decline in metals intensity to a degree, but not enough to invalidate the structural change hypothesis.

The next task is to isolate the parameters that were most responsible for the seeming structural shift. Three of the parameters are of particular interest: the output coefficient, the intercept, and the coefficient of the time trend. A decline in the output coefficient would indicate a change in the output mix. A decline in the intercept term would confirm the one-time shift view. The structural change view would get strong support if the time trend coefficient declined, among other parameters.

Overall, the statistical evidence on shifts in the output coefficient was rather weak for both the conventional and the extended models. The null hypothesis of no change in the output coefficient could not be rejected for all metals when the extended model was estimated. It could be rejected only for aluminum and copper with the conventional model. This result may be due to the choice of durable manufactures production as the output variable, which eliminates the changes in the share of durables in total output. Fluctuation in the share of durable manufactures in GDP is considered more cyclical than structural.

Evidence on the rate of technological change, or the time trend coefficient, was substantially different (see Annex Table 2). With the conventional model, the null hypothesis of no structural change in the rate of technical change is rejected at the 1% significance level for all the metals. With the extended model, the null hypothesis was rejected for four out of six metals but the power of the tests was substantially lower. This result appears to suggest that the rate of metal-saving technical progress significantly accelerated in the post-1973 period for most metals, except possibly for aluminum and zinc.

Test results for the intercept present a similar picture to those of the output coefficient. With the extended model, it is difficult to say that the intercept has shifted downward except for copper. The conventional model yields estimates supporting a one-time efficiency improvement in the post-1973 period.

Thus, what appears to have been a one-time shift in the efficiency of metals use could have been mostly the effect of higher energy prices.

In summary, test results lend some support to the view that the rate of metals-saving technological changes accelerated after the first oil price shock. This finding, however, opens the question of whether or to what extent the acceleration was caused by higher oil prices. Has the rate decelerated after oil prices declined? This last question cannot be answered yet. Results also indicate that the relationship between metals demand and durable manufactures production did not change; there was no strong evidence of "decoupling." Nor can the data support the view of a one-time efficiency improvement after the oil price shock. By extending the demand model to include all relevant input prices, including energy, it was possible to distinguish, to some extent, the effects of higher energy prices from those of structural change. A mis-specified demand model, such as the conventional demand model that leaves out relevant variables, can lead to the wrong inference about structural changes.[4]

V. CONCLUSIONS

The growth rate of world raw materials consumption slowed drastically after the first oil price shock, from 4-10% annually for most metals to 1-2%. For the

[4] Estimates of the extended demand model also reveal that variations in metals consumption are mostly explained by changes in durable goods production. The estimated demand elasticities with respect to durable goods range from 0.4 to 1.1. Copper, nickel and aluminum have higher output elasticities than tin, lead and zinc. Furthermore, the output elasticity does not appear to have significantly declined between the periods 1950-73 and 1974-85. The estimates generally indicate that metals are complements with energy and capital but substitutes with labor. Energy plays an important role in explaining aluminum and zinc consumption; the weak statistical significance in the case of aluminum improves dramatically when the wage rate variable is eliminated. Labor cost is a statistically significant explanatory variable for all the metals except aluminum. Capital stock has a negative coefficient for all metals except zinc, suggesting that they are substitutes in the production process.

agricultural raw materials, however, the decline has been far less pronounced. The fact that the decline started when oil prices increased would suggest that the negative effect on metals demand of energy-saving substitution, technological changes, and adverse macroeconomic impact of higher energy prices outweighed the positive effect through higher costs of synthetic substitutes. Any increase in cotton and natural rubber consumption that resulted from higher costs of synthetic fibers and rubber must have been relatively small.

Most of the decline in raw materials consumption took place in the industrial economies. In developing countries, the trend increase in the intensity of raw materials consumption per unit of output continued with only temporary interruptions at times of high oil prices, because of relatively rapid expansion of materials-intensive sectors and lags in adapting to latest materials-efficient technologies. The developing countries, particularly the rapidly industrializing developing countries, will continue to provide the main growth market for raw materials in the 1990s. Consumption growth in the formerly non-market economies also slowed down sharply during the past decade, but the dominant cause there is likely to have been poor economic growth.

The issue of whether the post-1973 decline in raw materials demand represents a permanent, irreversible, or "structural" change has important implications for developing countries heavily dependent on exports of those commodities. There have been divergent views on this issue. Statistical tests of alternative hypotheses suggest that the downturn has been only partly cyclical. Nor is there strong evidence to support the view that it was a one-time improvement in the efficiency of raw materials use. The most plausible interpretation, supported by statistical evidence, is that there has been an acceleration of materials-saving technological changes, probably induced by higher energy prices. It is an open question whether materials-saving technological changes will continue at the accelerated rate, when energy prices are lower. Experience over the last three years suggests that the rate may already have slowed down. If this indeed is the case, then the change cannot be billed as *structural*.

For the developing countries dependent on raw materials exports, the findings of this paper present a cautiously optimistic outlook for their exports than what was the prevailing view in early 1980s. The demand outlook even for lead and tin, once considered dead industries, now appear mildly promising. However, advances in material science could still pose a threat to these countries, especially if the rate of material-saving technical progress continues to accelerate despite lower energy prices.

ANNEX

TABLE 1: CHOW-TEST STATISTICS FOR STRUCTURAL CHANGE: ALL PARAMETERS

	CONVENTIONAL MODEL		EXTENDED MODEL	
ALUMINUM	7.86**	(5,26)	5.39**	(8,20)
COPPER	11.63**	(5,25)	3.06*	(8,19)
LEAD	15.74**	(4,28)	8.46**	(7,22)
NICKEL	9.78**	(4,22)	4.24**	(7,16)
TIN	8.58**	(4,28)	3.03*	(7,22)
ZINC	40.94**	(4,28)	0.98	(7,22)
TOTAL METALS	31.72**	(4,28)	4.01**	(8,20)

NOTE: F-TEST STATISTICS WITH THE NOMINATOR AND DENOMINATOR DEGREES OF FREEDOM SHOWN IN PARENTHESES.
* SIGNIFICANT AT 5% LEVEL. ** SIGNIFICANT AT 1% LEVEL.
SOURCE: CHOE (1989).

TABLE 2: CHOW-TEST STATISTICS FOR STRUCTURAL CHANGE: RATE OF TECHNICAL PROGRESS

	CONVENTIONAL MODEL		EXTENDED MODEL	
ALUMINUM	24.39**	(1,26)	0.90	(1,20)
COPPER	20.03**	(1,25)	5.28*	(1,19)
LEAD	34.56**	(1,28)	6.89*	(1,22)
NICKEL	19.36**	(1,22)	7.7C*	(1,16)
TIN	11.07**	(1,28)	8.06**	(1,22)
ZINC	9.78**	(1,28)	0.72	(1,22)
TOTAL METALS	35.64**	(1,28)	3.22	(1,20)

NOTE: F-TEST STATISTICS WITH THE NOMINATOR AND DENOMINATOR DEGREES OF FREEDOM SHOWN IN PARENTHESES.
* SIGNIFICANT AT 5% LEVEL. ** SIGNIFICANT AT 1% LEVEL.
SOURCE: CHOE (1989).

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